MODIS SEMI-ANNUAL REPORT: JAN/01/02 - JUN/30/02

Radiative Transfer Based Synergistic MODIS/MISR Algorithm for the Estimation of Global LAI & FPAR

(Contract: NAS5-96061)

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Summary of the algorithm. The objective of the contract is to develop a radiative transfer based synergistic algorithm for estimation of global leaf area index (LAI) and fraction of photosynthetically active radiation absorbed by vegetation (FPAR). The algorithm consists of a main procedure that exploits the spectral information content of MODIS measurements and the angular information content of MISR measurements to derive accurate estimation of LAI and FPAR. Should this main algorithm fail, a backup algorithm is triggered to estimate LAI and FPAR using vegetation indices. Both algorithms are capable of executing in MODIS-only or MISR-only mode, should cloud contamination, data frequency and spatial or temporal resolution requirements hinder a joint MODIS/MISR mode of operation. The MODIS-only mode of the algorithm requires a land cover classification that is compatible with the radiative transfer model used in the derivation. Such a classification based on vegetation structure was proposed and it is expected to be derived from the MODIS Land Cover Product. Therefore, our algorithm has interfaces with the MODIS/MISR surface reflectance product and the MODIS Land Cover Product. Validation of the LAI/FPAR product is an important part of algorithm development. Multiple validation techniques will be used to develop uncertainty information on Terra LAI/FPAR products. Successful validation will be accomplished if timely and accurate product uncertainty information becomes routinely available to the product users within two years after Terra's launch.

Summary of work performed during the second half of 2002 (January through June):

?? Preparation of IDS coarse resolution (0.05^0) version of MODIS LAI/FPAR algorithm. Tuning of LUTs. Generation of stand-alone 'C' version of the algorithm and its delivery (June 10, 2002) to Eric Vermote SCF for production of global coarse resolution monthly LAI/FPAR

?? Preparation for the outreach vegetation workshop at Montana July 15-19, 2002. Compilation of global monthly 1- and 4-km resolution composites datasets spanning period November 2000 through April 20002 from corresponding MOD15A2 collection 3 product. Preparing poster summarizing LAI/FPAR algorithm and validation experience.

?? Preparing to field campaign in Flakaliden, Sweeden, June 24-July 10, 2002. Sampling strategy is based on ETM+ imagery classification and segmentation procedures.

?? Talk at the Dickinson's IDS meeting, Boulder, CO, March 29, 2002.

?? Talk at the workshop 'Combating uncertainty with fusion, Woods Hole, MA, April 22-24, 2002.

?? Talk at the IWMMM-3 meeting, Steamboat Springs, CO, June 10-12, 2002.

?? Talk at the MISR Aerosol/surface workshop, Steamboat Springs, CO, June 13-14, 2002.

Coarse resolution (IDS) LAI/FPAR algorithm and product

Preliminary information

Following the review of the MODAPS system in December 2001, one suggestion from reviewer was for the MODIS Team to consider producing a selected set of products (no more then 10 for all of MODIS) at degraded resolution (space and time) in common land-atmosphere-ocean grid. These products will be easier to handle globally for evaluation and should also be much faster to process, allowing production of degraded resolutions multiple times during the life of the mission, given the limited re-processing capability and volumes of the Standard MODIS data products.

This task has been refined at a recent Science Discipline Team Lead meeting to be broken into two phases:

Phase I: The production of a degraded product data set to be distributed by the science team on a CD and ftp site.

Phase II: The implementation of a longer term strategy for IDS oriented degraded product generation.

For the Phase I, a sample of 9 Land products (Snow, Surface Reflectance, NDVI, LAI, FPAR, Fire, Surface Temperature, Land Cover, Albedo) will be produced covering at least a year of MODIS acquisition starting November 2000. Those products will be generated either from the coarse resolution level 2 surface reflectance product archived at the Surface Reflectance Science Computing Facility (Snow, Surface Reflectance, NDVI, LAI, FPAR), or derived from coarse resolution product archived at the other SCF's (Fire, Surface Temperature, Land Cover, Albedo). They will be produced on a common grid (linear latitude –longitude projection at 0.05 deg resolutions) and on a monthly, 32 days or yearly time step. A coarser resolution version of the product will also be produced to fit on a CD-ROM. The following table summarizes the details for each product:

Product	**Time step**	**Size 0.05 Meg**	**Size 0.25 Meg**	**Size 0.5 Meg**	**Size 1.0 Meg**	**Produced from**
Surface Reflectance	Monthly	4153	166	42	10	MOD09CRS
NDVI	Monthly	593	24	6	1	MOD09CRS
LAI/FPAR	Monthly	1187	47	12	3	MOD09CRS
Snow	Monthly	297	12	3	1	MOD09CRS
Spectral Albedo	32 days	4153	166	42	10	MOD43B3C
Land Temp	32 days	1187	47	12	3	MOD11B1
Land Cover	Year	25	1	0	0	MOD12QC
Fire	Monthly	297	12	3	1	MOD14CRS

Description of the IDS LAI/FPAR product

The MODIS LAI/FPAR algorithm was adjusted for the required resolution (0.05^0). This involved tuning of the LUTs of the algorithm without any changes to the code. The input to the algorithm is coarse resolution 6 biome land cover map(currently reprojected to six biomes MOD12Q1 2002002 SDS 3) and monthly composites of 0.05 degree resolution surface reflactances (IDS L3 surface reflectances). The output of the algorithm consist of three layers: 1)LAI, 2)FPAR, 3)LAI_FPAR_QC. The LAI map generated by coarse resolution LAI/FPAR algorithm is shown at **Figure 1**.

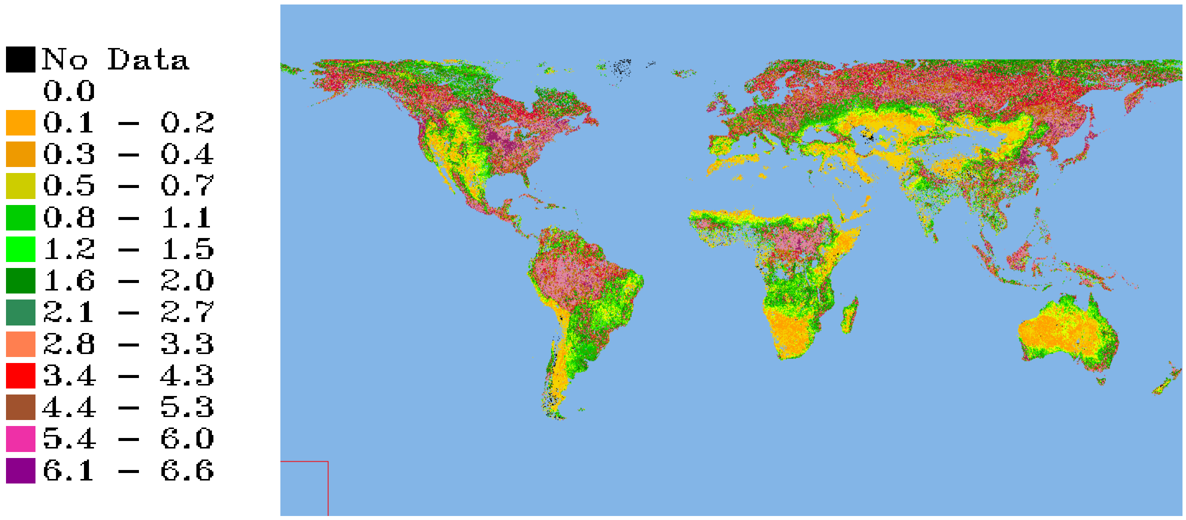


Figure 1: Global 1/20 degree LAI image for August 2001

Coarse resolution LAI/FPAR product will be generated at GSFC SCF (with Eric Vermote). We delivered (June 10, 2002, in collaboration with Peter Votava and Nazmi Saleous) stand-alone application which ingest .hdf files with surface reflectances and binary land cover to LAI/FPAR algorithm and outputs .hdf file with LAI/FPAR/QC.

Specification of the product

1) QC interpretation
   - 0- Main algorithm, no saturation
   - 1- Main algorithm, saturation
   - 2- Back-up algorithm due to bad geometry
   - 3- Back-up algorithm due to main algorithm fails
   - 255- fill value (bad input/non-vegetation/cloudy)
2) Scale factors (to convert from DN values to biophysical quantities)
   LAI/FPAR- 1/1000
   LAI/FPAR_QC- 1/1

Future development

For the phase II we are planning to
1) fix possible bugs
2) incorporate land cover based on at least one year worth of MODIS data and possibly automate process of incorporation of the most recent version of land cover.

Compilation of monthly global data sets of MODIS LAI/FPAR

Preliminary information

This work was done as a part of preparation to vegetation workshop (outreach meeting) in Montana July 15-19, 2002. Outreach meetings are organized for different communities of scientists working with MODIS data to advertise their products for prospective users, get feedback and make product more convenient to use.

Vegetation workshop will be focused on VI/LAI/FPAR/NPP products. For this workshop we prepared poster summarizing LAI/FPAR algorithm and validation experience. Several LAI/FPAR posters-maps printed out to visualize vegetation dynamics through the year. The key feature for this workshop is presentation of improved data set of MODIS LAI/FPAR. New data set is based on MOD15A2 collection 3 LAI/FPAR data spanning period November 2000 through April 2002. Our data set prepared in two versions:

1) **1-km monthly global composites**
2) **4-km monthly global composites**

The composting procedure of four 8-day MOD15A2 LAI/FPAR values to monthly composites is based on selecting the best quality data from four 8-day MOD15A2 data. In the case of low quality retrievals (main algorithm, saturation or back-up retrievals) for all four values, maximum FPAR data were selected to represent value for the corresponding month. The 4-km resolution data set was prepared on the basis of spatial averaging of corresponding of 16 values of 1-km pixels. The spatial resolution of 4-km was selected to match resolution of AVHRR. The 4-km data set will be distributed on the workshop on CDs. Sample of LAI/FPAR map at 4-km resolution is shown at **Figure 2 and 3**. Both 1- and 4-km data sets are implemented in flat binary format (not .hdf) which fasilitate handling of data. We submitted these data sets to University of Montana to generate corresponding NPP product.

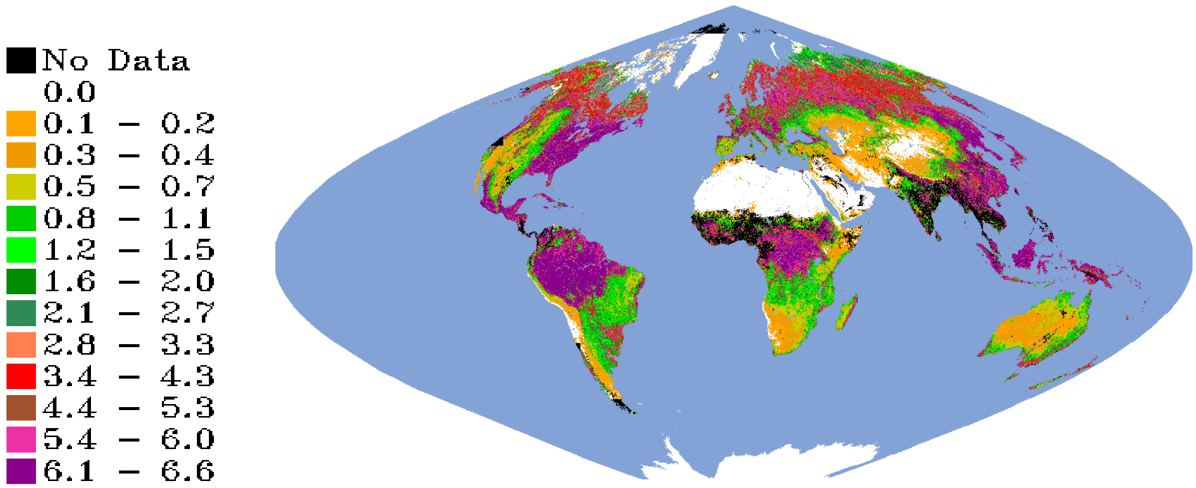


Figure 2: Global 4-km LAI image for August 2001

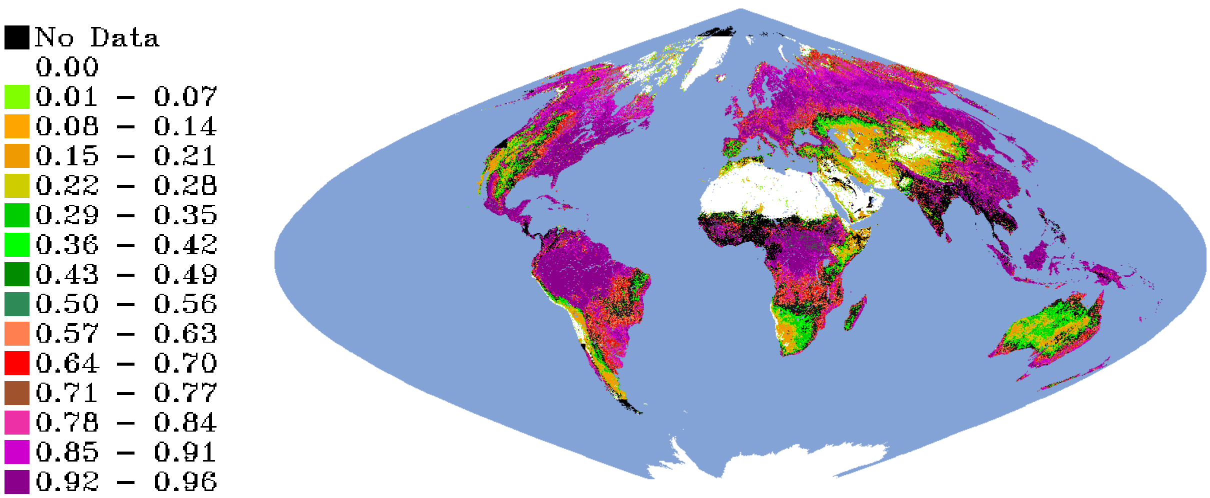


Figure 3: Global 4-km FPAR image for August 2001

Future directions

1) Compiled data set will be updated continuously as new MODIS data will be available. This includes extension in time as well as incorporation of new versions (such as collection 4 data).
2) Extension of AVHRR time series of LAI/FPAR (Based on NDVI) with corresponding MODIS LAI/FPAR

Design of sampling strategy for Flakaliden (Sweden) field campaign, June 24- July 10, 2002

Preliminary information

The Boston University MODIS LAI/FPAR team prepared field campaign at Flakaliden Sweden (**Figure 4**) during June 24- July 10, 2002. More then 40 researchers from USA, Estonia, Finland, Germany, Italy, Sweeden are planned to participate. This campaign is targeted to address the following science questions:

1) **Validation of MODIS LAI and FPAR products**
2) **Study of optical properties of needle forest vegetation at leaf and canopy scales**
3) **Investigate if MODIS FPAR suggestive of vegetation gross production**

Building on our previous experience (Shabanov, et al 2002, Tian, et al., 2002(a), 2002(b), Wang et al., 2002) we use ETM+ fine resolution imagery to prepare sampling strategy for this campaign (see below). Ground measurements of LAI with LAI-200 plant canopy analyzer, canopy bottom hemispherical transmittance and top of canopy hemispherical reflectance (from helicopter) will be done using LI-1800 and ASD handheld spectroradiometer. Optical properties of leaves from dominant species will be measured with LI-1800.

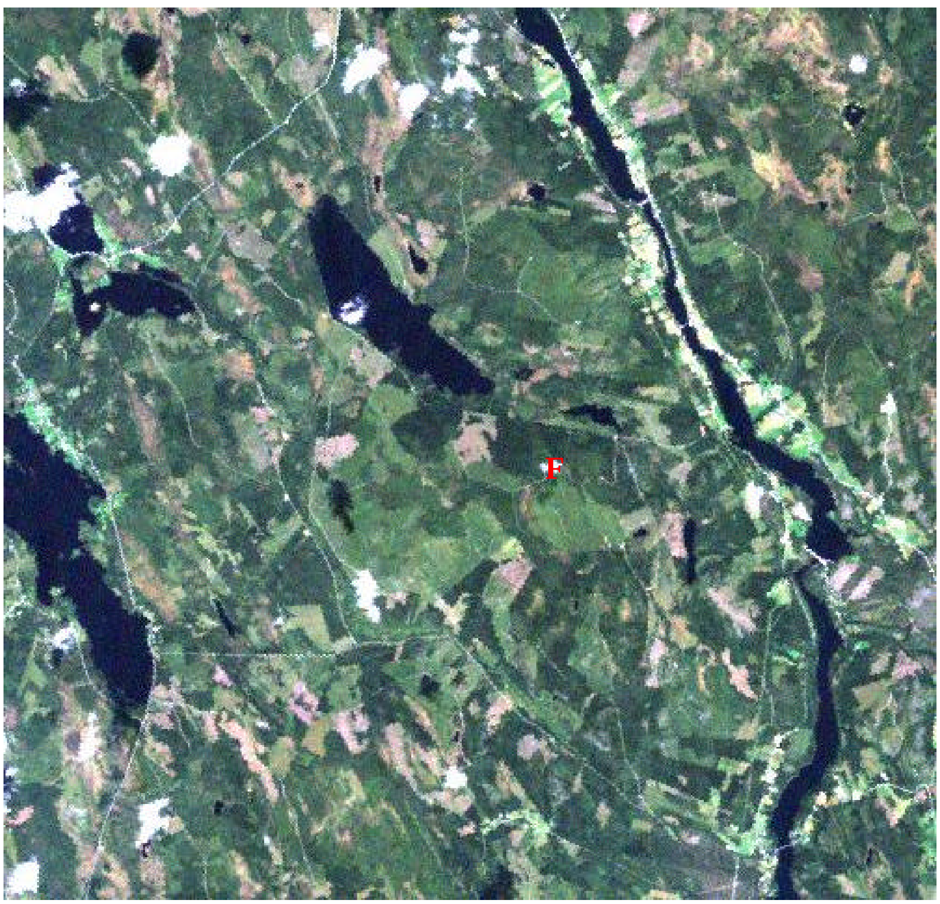


Figure 4: ETM+ true color image (Aug 24, 2001), centered at Flakaliden (64^0 07'N, 19^0 27'E)

Sampling strategy

To develop a sampling strategy, a 30 m resolution ETM+ scene (path 194 row 15) containing Flakaliden site was degraded to a 1 km resolution image. **Figure 5** shows the distributions of 1 km NDVI (Normalized Difference Vegetation Index) and RSR (Reduced Simple Ratio) values for the degraded image.

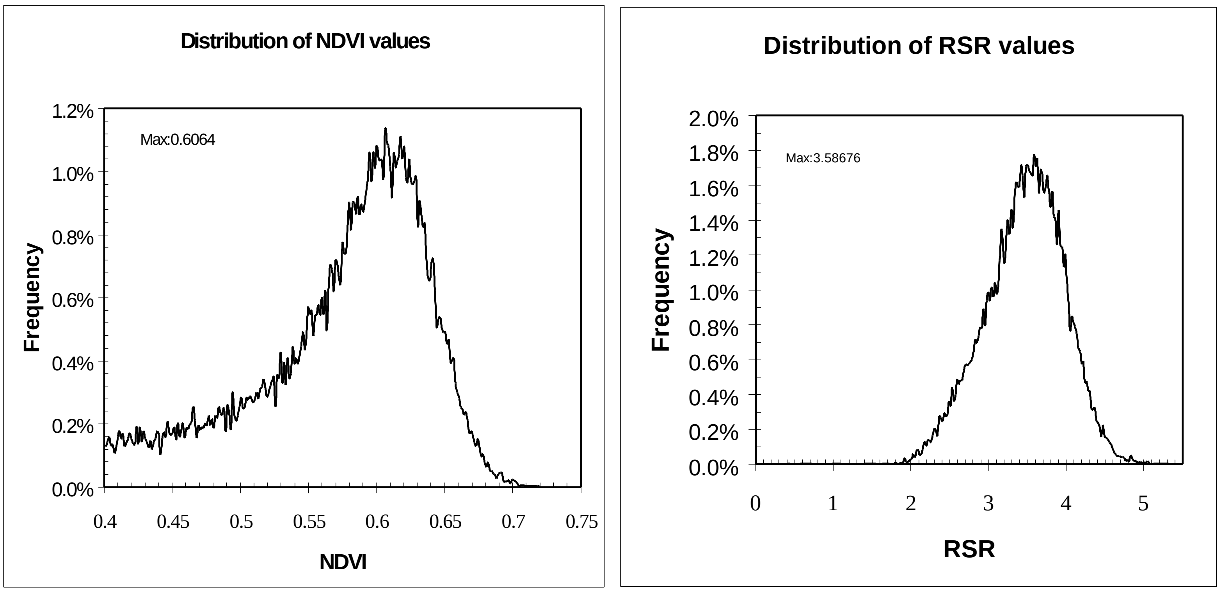
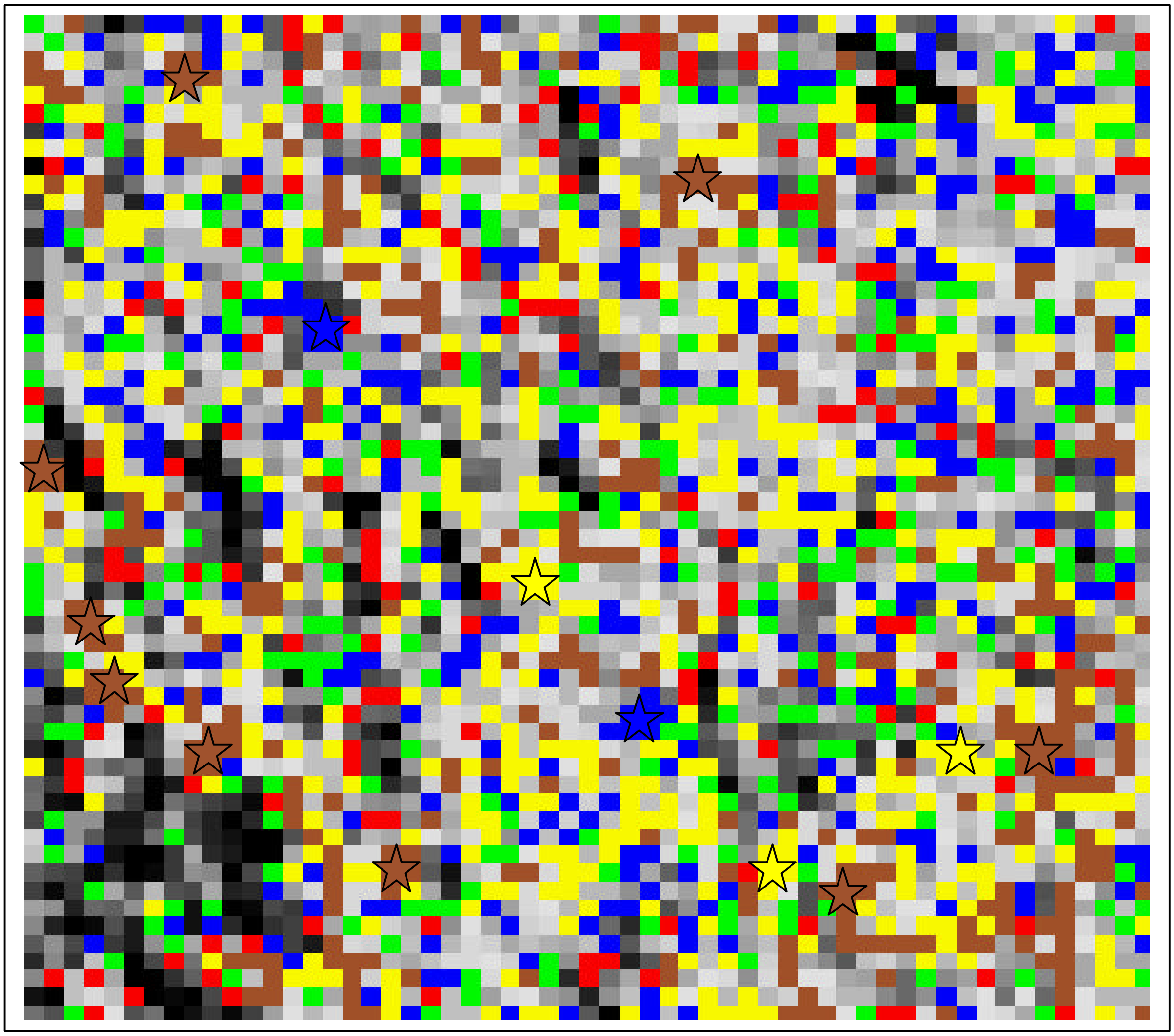


Figure 5: Distribution of 1 km NDVI and RSR values over the 200 by 200 km area with Flakaliden in the center.

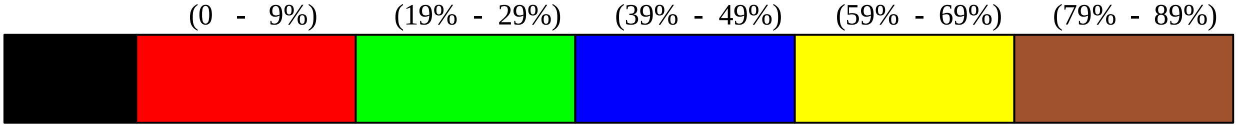
The sets of NDVI and RSR values were divided into 10 classes in such a way that each class contained the same number of pixels (10%). The division was made as follows. The maximum values of NDVI and RSR were identified and 5 % of all pixels were taken from both left and right sides of the maximum to form one class. Other classes were produced by selecting 10% of pixels sequentially from the right and left sides of the classes containing the maximum value. Classification is different for NDVI and RSR distribution. As adjacent classes may contain close NDVI and RSR values, only five non-adjacent classes were left for the further analysis. Finally, the color map was produced (**Figure 6**).

NDVI and RSR 1 km resolution maps were created on the basis of the above color table and resulting RSM map is shown also at **Figure 6**. The further analysis would be based on the RSR map only, the NDVI map would be used to extract NDVI values for selected locations. On RSR map, we tried to select clusters of pixels with the same RSR values for each range. Each cluster contains at least 4 pixels.



NDVI Value (Max = 0.6064, 63.95%)

Others	(0.4000, 0.4692)	(0.5234, 0.5510)	(0.5724, 0.5875)	(0.6001, 0.6140)	(0.6240, 0.6417)
	(0 - 9%)	(19% - 29%)	(39% - 49%)	(59% - 69%)	(79% - 89%)



	(13% - 23%)	(33% - 43%)	(53% - 63%)	(73% - 83%)	(93% - 100%)
Others	(2.8277, 3.0807)	(3.2494, 3.3970)	(3.5235, 3.6500)	(3.7765, 3.9452)	(4.1561, 5.500)

RSR Value (NDVI>0.4) (Max = 3.5868, 58.16%)

Figure 6: RSR map for the (50x50 km) area. Clusters of pixels with the same RSR values are shown by stars. Color table for NDVI and Reduced simple ratio is shown below the image.

For each selected group of pixels, a central pixel was defined. The selected 1 km pixels were then identified on the 30 m resolution ETM+ image to develop a measuring strategy within each of them.

The question was how we would compare the field and ETM+ data. A pixel by pixel comparison is not feasible for two reasons. First, the measured area is smaller than the resolution of the ETM+. Therefore, the individual measurements are not representative of 30 m ETM+ pixels and can't be reliably matched with them. Second, because of a possible high variance of measurements over short distances, there might be some errors associated with field measurements and mismatch of pixels between the measurements and the image. To validate the algorithm, it is essential to identify multi-pixel patches in the image data.

In the analysis of remotely sensed imagery, pixels are assumed to be representative samples of objects in the scene. When pixels are large relative to ground objects, individual pixels often cover parts of two or more objects, resulting in mixed pixels, and the effectiveness of analysis is undermined (MacDonald and Hall, 1980). Similarly, when pixels are small relative to the objects, internal variance of the objects adversely affects the analysis (Markham and Townshend, 1981). The ideal situation is when the elements of analysis in the image correspond to the objects in the scene (Woodcock and Harward, 1992). The objective of image segmentation is to partition the image into a set of regions, which correspond to objects in the ground scene and will serve as the basis of further analysis. Therefore, the spectral attributes of regions defined via segmentation may more accurately be grouped into categories than the pixels comprising the region when taken singly (Woodcock and Harward, 1992).

We use a segmentation procedure to generate groups of ETM+ pixels, or regions, corresponding to patches of vegetation to serve as the basis of validation of the MODIS LAI/FPAR algorithm. The segmentation algorithm groups pixels into patches based on their spectral similarity and adjacency. The sample of the resulting maps (**Figures 7**) yields patches corresponding to identifiable features in the landscape. We will take measurements at 18 1-km areas sampling each patch.

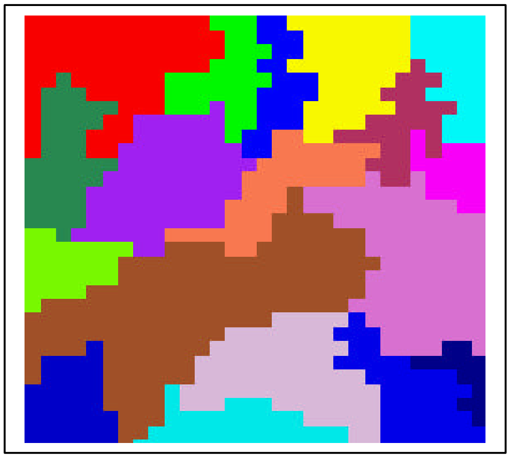


Figure 7. Maps of the two (1x1 km) regions produced by using the segmentation procedure described in the text. Other patch maps are available upon request.

Referernces

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